Australian Agricultural and Resource Economics Society

52nd Annual Conference, 2008

Net Benefits from growing lucerne (*Medicago sativa*) on the Broken Plains of north eastern Victoria

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Abstract. Clearing of trees and native vegetation over the past 160 years has led to increasing rates of dryland salinization in the Goulburn-Broken Catchment area. In its dryland section, within the Goulburn Highlands, South West Goulburn, and the Broken Highlands sub-catchments, hydrologic balance exists. But in the Riverine Plains comprising the Goulburn and Broken Plains sub-catchments, where average annual rainfalls are less than 600 mm per annum, it will be many decades before hydrologic balance is achieved. This study is set in the Broken Plains sub-catchment where over the next 100 years, it is expected that deep drainage of annual rainfall will cause watertables to rise to within two metres of the ground surface. Such rises of groundwater will lead to marked land degradation, initially in the form of induced waterlogging and ultimately increased dryland salinity. There is therefore a critical need to redress this increasing problem. One main way of doing so is by introducing deep-rooted perennial species such as lucerne into the landscape. Lucerne has a higher level of water extraction than annual crops and pasture. However, one of the barriers to farmers changing from annual subterranean clover pasture to lucerne is uncertainty about the effects of such a change and the chance of reduced average profit or its volatility. This study seeks to reduce that uncertainty by investigating changes in profitability and cash flow across the Broken Plains sub-catchment where farming with lucerne replaces cropping with subterranean clover pasture.

1. Introduction

Although the area of the Broken Plains sub-catchment (280,000 hectares) is only 15 percent of the total area of the dryland section of the Goulburn-Broken Catchment Area (1.8 million hectares), around 60 percent of the gross value of production is derived from within it. It is a mixed farming area where the ratio of crops to pasture is approximately 60:40 and the grazing activities comprise 80 percent sheep and 20 percent cattle.

Increasing rates of dryland salinization have been predicted to occur in the Goulburn-Broken Catchment area (Goulburn-Broken Catchment Management Aurthority 2002). However, presently, the Broken Plains sub-catchment moment little salt with the amount being the lowest of all the dryland sub-catchments (Goulburn-Broken Catchment Management Aurthority 2002). Nevertheless, Sinclair Knight Merz (1999) identified it as likely to contribute the greatest increases in dryland salinity over the next 100 years with watertables rising to within two metres of the natural surface over 20 to 40 per cent of the area. Rising watertables will also be accompanied by wide scale waterlogging, and the net effect will be a substantial loss of economic value through a lowering in the productivity of agricultural production and a threat to buildings, roads and general infrastructure.

The major cause of increases in dryland salinization has been attributed to over-clearing of native woodlands by European settlers over the past 160 years or so (Allison *et al.*1990, Macumber 1991, Hatton and Nulsen 2001). Over-clearing has had the effect of disturbing the pre-existing hydrological balance in the landscape and replacement of trees with shallow rooted annual crops and pastures has led to increasing levels of recharge to ground water. Rising water tables, especially those of a saline nature, have an extremely detrimental effect on the physiology of crops and pastures once they reach levels of two metres below ground level. One way to redress the problem of deep drainage to watertables is to introduce deep-rooted perennial plants into the landscape. Lucerne (*Medicago sativa*) is such a plant and has many advantages over annual crops and pastures when grown in farming systems.

Researchers have studied the agronomic, hydrologic and economic benefits of including lucerne into farming systems. Lucerne provides a greater amount of dry matter than subterranean clover and allows for higher stocking rates with increases in animal production (Reeve and Sharkey 1980, Crawford and Macfarlane, 1995). Lucerne produces out of season green feed when subterranean pastures have senesced. This is particularly important during the summer months when thunder storms stimulate plant growth for finishing carry over stock and the growing out and fattening of purchased store stock (Reed *et al.* 1972). Lucerne is effective in controlling weeds due to maintaining a high water deficit in surface soils and its alleliopathic behaviour that would become increasingly important as weeds become more resistant to herbicides (Dunin *et al.* 2001, Latta *et al.* 2001, Monjardino *et al.* 2004). Lucerne produces more soil nitrogen than subterranean clover that improves yields and quality of subsequent crops (Peoples *et al.* 1998, Angus 2001). An extremely important environmental benefit of lucerne is its ability to redress hydrologic imbalance because of its ability to extract greater amounts of soil moisture than annual crops and pasture thereby minimizing deep drainage to watertables (Holford and Doyle 1978, Angus *et al.* 2001, Dunin *et al.* 2001, Hirth *et al*. 2001, Ridley *et al.* 2001, Whitfield 2001 and Dolling *et al.* 2005). Increases in profitability from including lucerne in farming systems have been reported by Kingwell and Pannell (1987), Morrison *et al.* (1991), Oram *et al*. (1991), Hirth *et al.* (2001), Kingwell *et al.* (2003), Flugge *et al.* (2004) and Ransom *et al.* (2006)

The idea has therefore arisen that farming with lucerne rather than growing crops with subterranean clover would improve productivity, hydrology, and subsequently profitability of farming systems in the Broken Plains sub-catchment.

Barriers to the adoption of lucerne

Although research has shown that net benefits may accrue to farming businesses in the Broken Plains from including lucerne in their farming systems, several barriers have been identified (Ransom et al. 2006). These are: lucerne is expensive to establish and has a high risk of failure; having established lucerne, it is hard to remove to make way for successive crops; the first crop grown after lucerne does not yield as well as a crop grown after subterranean pasture and producers are not convinced that growing lucerne provides subsequent economic benefit to their farm businesses given the involvement of added risk and uncertainty.

Aims of this study

The aim of this study was twofold. First, to determine whether the advantages of growing lucerne found from research would translate into agronomic and hydrologic benefits for farming businesses on the Broken Plains. Second, to determine whether farming with lucerne would result in higher financially feasible profits being earned instead of farming with subterranean clover pasture.

2. Materials and methods

Six case study farms were identified where farming with lucerne was substituted for cropping with subterranean clover. Of those six, one grew pasture for grazing sheep and producing fodder, one carried out a system of companion cropping with lucerne, and four grew lucerne as a phase in their pasture-cropping programs. Case studies are a legitimate method of discovering cause and effect relationships that can be generalized for the benefit of a wider population (Glaser and Strauss 1967, Ragin 1987, Eisenhardt 1989,Yin 1998).

Data was collected from the case study farmers to develop whole farm cash flows for their farming businesses. Analyses of whole farms for unique farm businesses allowed full cognizance to be taken of the dynamic, complex and stochastic nature from farming with lucerne compared with farming with subterranean clover (Malcolm 1990).

Benefit Cost Analyses (BCA's) were carried out for the alternative farming systems on the case study farms (Makeham and Malcolm 1993, Sinden and Thampapillai 1995). From the BCA's, Net Present Values (NPV's) after tax were calculated as a measure of the amount of wealth generated by the farming systems for the whole farm businesses. The discount rate used for calculating NPV's was a nominal risk free rate of 8.5 per cent per annum. It was the average interest rate paid on long term government bonds over the period 1986 to 2006 (Australian Bureau of Census and Statistics 2007).

The length of the rotations for farming with lucerne compared with farming with subterranean clover were different for the various farms with the exception of the Cosgrove farm where each were over a period of 12 years. For Bungeet the farming with lucerne rotation was over 12 years but the farming with subterranean clover rotation had a length of 10 years. The comparative rotation lengths for Burramine were 8 compared with 9 years. At Dookie, the lengths were 8 years with lucerne and 10 years with subterranean clover whilst for Stewarton the periods were 15 and 14 years and for Tungamah 11 and 9 years. Because the time over which the rotations were conducted differed, the NPV's were converted to Annualised Net Present Values (ANPV's) (Van Horne 1977, Gitman 1997).

In converting real benefits and costs to nominal values, an inflation rate of 3.8 per cent was used. It was the average rate of the consumer price index over the 20 year period from 1986 to 2006 (Australian Bureau of Census and Statistics 2005, Australian Bureau of Census and Statistics 2007). The same rate was applied to both benefits and costs because declines in the terms of trade were identical to productivity gains for mixed farms from 1975 to 2005 (Productivity Commission 2005).

Although a risk free discount rate was used, farming is a very risky business and risk has to be accounted for in calculating the relative profitability of alternative investment options. In this case, farming with lucerne compared with farming with subterranean clover (Anderson *et al*. 1977, Boehlje and Eideman, 1984, Hardaker *et al*. 2004, Malcolm *et al*. 2005). Risk was handled by entering probability distributions for uncertain variables such as yields, prices and costs of supplementary feed for livestock in the BCA's. The NPV's and ANPV's were calculated by running the BCA's through a Crystal Ball® Monte Carlo simulation model.

In conducting the BCA's overhead costs for the two farming systems, with the exception of depreciation of machinery that was included in the calculations of taxable income were ignored because it was assumed that they would be identical. However, the budgets included initial capital investments in land at $2,000 per hectare and machinery. Over the period of the analyses, capital was included for machinery replacement, pasture establishment, lime, and livestock. Salvage values were recorded for livestock prior to undertaking successive crops as were salvage values in the final year of the analyses for land, lime that was not used for neutralizing soil acidification and machinery (Makeham and Malcolm and 1993, Trapnell and Malcolm 2004).

Having calculated the more profitable farming systems for the various case study farms, financial analyses were conducted to determine their relative feasibilities. This was achieved by calculating cumulative net cash flows for the alternative farming systems. From the cumulative net cash flows the main issues of importance to the investor were the peak debt, the year in which the peak debt occurred, and the time taken (pay-back period) for cash deficits in the investment program to be repaid from net income (Barry *et al.* 2000).

Following the economic and financial analysis of case study farms, the same analyses were conducted for the Broken Plains sub-catchment. Systems for farming using lucerne compared with farming with subterranean clover were generalized using information from case study farmers, agronomists and scientific researchers. For farming with subterranean clover, the rotation comprised four years of pasture with six successive crops. The crops commenced with canola, followed by wheat, wheat, canola and finishing with a crop of triticale. The rotation incorporating lucerne comprised six years of lucerne pasture followed by a six year cropping regime of wheat, canola, wheat, wheat, canola finishing with a crop of wheat. The number of years of lucerne followed the recommendation of Hirth *et al.* (2001) that was based on research at Rutherglen, adjacent to the Broken Plains, where they were of the opinion that hydrological balance could be achieved if lucerne comprised 50 per cent of the crop-pasture rotation.

Although Sinclair Night Merz (1999) stated that by 2100, land degradation through water-logging followed by salinisation would have ruined 42,500 to 85,000 hectares in the Broken Plains, the future is not known with certainty. The analyses therefore invoked the precautionary principle stated by Wills (1997):

> ‘Where there are threats of serious or irreversible environmental damage to the environment, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by careful evaluation to avoid serious or irreversible damage to the environment, and an assessment made of the risk-weighted consequences of various options.’

Benefit –cost analyses were made for periods of 60, 90, or 120 years from the present that it may take for watertables to rise to two metres below the natural surface. Discounting carried out for case study farms was conducted over a period of equal to or less than 30 years. That period is theoretically uncontroversial because it is about the limit in time over which capital markets operate to determine the marginal productivity of capital and the return on investments (Randall 2006, Schilizzi 2006). However, the period of discounting for the whole catchment area would be over time frames that involve intergenerational equity. Portney and Weyant (1999), Wietzman (1998), Newell and Pizer (2003), and Pannell and

Schilizzi (2006) have investigated this issue. Their conclusions suggest the possibility that it may be essential to incorporate declining discount rates into benefit-cost methods for evaluating long-term environmental projects. In keeping with those sentiments, in this analysis the real discount rate for analyses of less than 30 years of 4.49 per cent was lowered to 3.37 per cent for periods of 31 to 100 years and to 2.00 percent for the period of 101 to 130 years. Holding the long term inflation rate constant at 3.84 per cent and using 'Fishers Equation' to convert real rates to nominal rates (Fisher 1991), the real rates become nominal rates of 8.50 percent below 30 years, 7.34 percent from 31 to 100 years and 5.92 per cent for the period of 101 to 130 years.

The BCA analyses were conducted for an area that is liable to become degraded of 85.000 hectare. The number of farms in that area was assumed to be 110, therefore the items of machinery per farm were multiplied by 110. The value of land that was liable to degrade was valued at an initial cost of $2,000 per hectare. It was assumed that after 30, 60, or 120 years, land degradation would occur at a compound rate of 10 percent per annum for a further 10 years. Consequently, the value of benefits and the capital value of land would also be reduced over a 10 year period at a compound rate of 10 per cent per annum.

3. Results

Case study farms

Farming with lucerne compared with farming with subterranean clover was shown to have many advantages in the farming systems carried out by the case study farmers. These related to the provision of greater amounts of dry matter with consequent increases in stocking rates, the provision of out of season green feed for finishing carry over stock and fattening store lambs, the ability of lucerne to produce high quality silage and hay, and its role in controlling weeds, particularly prior to commencing the cropping phase of the rotation. The control of weeds also resulted in lower costs for herbicides.

An important issue was the increase in soil nitrogen produced by lucerne that enabled higher yields of subsequent crops and improvements in their quality with a reduction in the cost of applying nitrogen fertilizers. In all cases, protein levels in wheat were increased by an average of 2 percent with the Tungamah case study farmer commenting that occasionally their wheat tested at a protein level of 14 percent.

The case study farmers also agreed that lucerne had the effect of improving soil structure on their duplex soils with a reduction in waterlogging that used to occur during wet winters. Their general observation was that soils were drier after a phase of lucerne, and that unless heavy summer and early autumn rains were received to recharge the soil profile, the first crop after lucerne had a lower yield. That effect, however, was negated by higher yields and quality of grain in later years of the rotation. Overall, the case study farmers believed that greater efficiency in the use of soil moisture could be achieved by including lucerne in their farming systems.

There was also belief that the presence of green lucerne paddocks throughout the year added to the aesthetic appearance of their farms. A negative aspect from growing lucerne was experienced by the Tungamah case study farmer where during the drought year of 2002, 'sink holes' of varying size appeared in the lucerne paddocks. They were quite numerous and thought to arise from the high water extracting ability of lucerne in the year of low rainfall.

Their effect was to disrupt the activities of spraying and fertilizer spreading and to generally hamper safe movement across the paddocks during the mustering of stock.

The results of the analyses of profit for the case study farms is shown in Table 1 and their peak debts and pay-back periods from the financial analyses are displayed in Table 2. In Table 2 peak debts all occurred in the first year of the analyses.

Table 1. Mean Annualized Net Present Values for case study farms in the Broken Plains for farming with lucerne compared with farming with subterranean clover with nominal discount rates of 8.5 per cent per annum.

Farm location	System for farming with lucerne	Mean ANPV farming with lucerne	Mean ANPV farming with subterranean clover
		$	$
Bungeet	Phase farming	390,847	282,389
Burramine	Pasture only	123,843	109,019
Cosgrove	Phase farming	136,527	111,124
Dookie	Companion farming	141,197	113,108
Tungamah	Phase farming	462,407	362,148
Stewarton	Phase farming	676,755	249,690

Mean ANPV’s shown in Table 1 for farming with lucerne are higher than for farming with subterranean clover, hence it appears to be a more profitable investment that would add a greater amount of wealth to the farm business.

Apart from determining the choice of one farming system over another based on the relative magnitudes of their Mean Annualized Net Present Values, a further test to determine the better choice was to compare the cumulative distribution functions (CDF’s) of the alternative systems. We know from comparing the Mean ANPV’s for the two farming systems that farming with lucerne could be the preferred option to farming with subterranean clover. However, since the ANPV is a stochastic measure and has different values for ANPV for each level of probability, we need to know that farming with lucerne is preferred to farming with subterranean clover over the total range of probabilities from 0 to 1. This is achieved by preparing CDF functions for each alternative farming system then comparing the two. By making that comparison with the assumption that farmers prefer more wealth to less wealth, it was found that the option of farming with lucerne dominated the option of farming with subterranean clover. That is, for each level of probability in the CDF curves, the ANPV for farming with lucerne was always lower than the ANPV for farming with subterranean clover. Another way of stating that is; the CDF curve for farming with lucerne was always below and to the right of the CDF curve for farming with subterranean clover. It is therefore possible to state that for First Degree Statistical Dominance (FSD), the option of farming with lucerne dominates the option of farming with subterranean clover and would be the option chosen for investment. (McConnell and Dillon 1975, Vose 2000, Hardaker *et al.* 2004.

Table 2. Peak debts and pay-back periods from cumulative net cash flows for case study farms in the Broken Plains

Farm location	Farming with lucerne		Farming with subterranean clover	
	Peak debt	Payback period	Peak debt	Payback period
	$	Years	$	Years
Bungeet	1,981,909	7	2,093,597	11
Burramine	1,377,946	12	1,323,777	14
Cosgrove	1,627,489	13	1,621,897	17
Dookie	1,581,497	13	1,598,951	15
Stewarton	1,410,696	12	1,416,643	21
Tungamah	2,777652	9	2,861,498	13

The peak debts for the two farming systems occurred in the first year of the analyses. The peak debt for the Burramine and Cosgrove farms was slightly higher for farming with lucerne than farming with subterranean clover. For the other four farms it was slightly lower. For farming with lucerne, the peak debt was able to be extinguished quicker than farming with subterranean clover which would make it the preferred option for investment.

Broken Plains Sub-catchment

In Table 3, the median NPV's for the times of 70, 100 and 130 years are displayed for an area of 85,000 hectare.

Table 4. Mean Net Present Values for the Broken Plains for farming with lucerne compared with farming with subterranean clover

Period of analysis	Mean NPV farming with lucerne	Mean NPV farming with subterranean clover
Years	$ m.	$ m.
70	382.6	246.3
100	429.6	281.4
130	455.9	289.9

For all of the periods of analysis, the mean NPV for farming with lucerne is considerably higher than that for farming with subterranean clover. An analysis of stochastic dominance revealed that the decision making option would favour farming with lucerne because again, for First Degree Statistical Dominance (FSD), the option of farming with lucerne dominates the option of farming with subterranean clover (McConnell and Dillon 1975, Vose 2000, Hardaker *et al.* 2004.

Results of the financial analysis are displayed in Table 4.

Table 4. Peak debts and pay-back periods from cumulative net cash flows for farms in the Broken Plains that could become degraded

Farming with lucerne		Farming with subterranean clover	
Peak debt	Payback period	Peak debt	Payback period
$ m.	Years	$ m.	Years
183.7	8	189.4	12

In Table 4 it is shown that the peak for farming with lucerne is lower than that for farming with subterranean clover. The components of the peak debt comprise the same capital value for land at $2,000 per hectare and the initial amount of machinery capital invested for farming with lucerne of $199.6 million compared to $198.0 million for faming with subterranean clover. However, the higher initial capitalization for farming with lucerne was offset during the first year of the analysis where the annual net benefits after tax were $34.9 million compared with $27.7 million for farming with subterranean clover. The analysis for financial feasibility revealed that the option of farming with lucerne would be preferred to farming with subterranean clover because the peak debt was liquidated over a shorter period.

4. Discussion and conclusions

The qualitative analysis of the six case study confirmed that farming with lucerne provided greater benefits than farming with subterranean clover. These related to the provision of greater amounts of dry matter with consequent increases in stocking rates, the provision of out of season green feed for finishing carry over stock and fattening store lambs, the ability of lucerne to produce high quality silage and hay and its role in controlling weeds, particularly prior to commencing the cropping phase of the rotation. The control of weeds also resulted in lower costs for herbicides. Weed control is likely to become increasingly important as some weed species become increasingly resistant to herbicides.

An important issue was the increase in soil nitrogen produced by lucerne that enabled higher yields of subsequent crops and improvements in their quality with a reduction in the cost of applying nitrogen fertilizers. In all cases, protein levels in wheat were increased by an average of 2 percent with the Tungamah case study farmer commenting that occasionally their wheat tested at a protein level of 14 percent.

The case study farmers also agreed that lucerne had the effect of improving soil structure on their duplex soils with a reduction in waterlogging that used to occur during wet winters. Their general observation was that soils were drier after a phase of lucerne, and that unless heavy summer and early autumn rains were received to recharge the soil profile, the first crop after lucerne had a lower yield. That effect was negated by higher yields and quality of grain in later years of the rotation. Overall, the case study farmers believed that greater efficiency in the use of soil moisture could be achieved by including lucerne in their farming systems.

There was also belief that the presence of green lucerne paddocks throughout the year added to the aesthetic appearance of their farms. A negative aspect from growing lucerne was experienced by the Tungamah case study farmer where during the drought year of 2002, ‘sink holes’ of varying size appeared in the lucerne paddocks. They were quite numerous and thought to arise from the high water extracting ability of lucerne in the year of low rainfall. Their effect was to disrupt the activities of spraying and fertilizer spreading and to generally hamper safe movement across the paddocks during the mustering of stock.

All of the case study farmers believed that the profitability of their farm businesses had improved as a result of lucerne being introduced into their farming systems. This was born out by the quantitative analyses of profit where the ANPV's of farming with lucerne were compared with those for farming with subterranean clover. In all cases, the ANPV's, and hence the contribution of wealth to the farm businesses were higher with lucerne than farming with subterranean clover. The financial analyses showed that as well as being more profitable, the investment of farming with lucerne was financially feasible.

The conclusion for the case study farms was that the investment of farming with lucerne rather than farming with subterranean clover improved the farms' productivity, aesthetic value, and environmental benefits. Investing in the change was found to increase profits and to be financially feasible.

In extending the quantitative analyses to 40 per cent of the Broken Plains, an area of 85,000 hectares comprising an estimated 110 farms, BCA's and financial analyses revealed that farming with lucerne compared with farming with subterranean was more profitable and financially feasible.

Thus far, this project has addressed the private benefits for farming with lucerne on the Broken Plains. Further work will involve first determining the public benefits occurring from the use of lucerne to prevent the rise in watertables with the consequent damaging effect on public infrastructure and second, an investigation into policy instruments that may be used to increase the use of lucerne in farming systems on the Broken Plains.

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